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USE OF ROCKS TO OBTAIN FOAM GLASS

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It is established that in principle opoka from the Kyngrakskoe deposit can be used as raw material for obtaining heat-insulating foam glass by a technology that eliminates the melting process. The optimal sintering temperature, powder dispersity and mass content of sodium hydroxide additive, which make it possible for amorphous foamed material to form from opoka during the heat-treatment process, are determined.

Key words: opoka, foam glass.

The problem of heat conservation in buildings and industrial, residential and community structures as well as the pipes of district heating plants has become urgent worldwide. One of the heat-insulation materials in greatest demand is foam glass, characterized by a complex of unique physical-chemical properties [1, 2]. One problem holding back the mass production of foam glass is a shortage of raw material — process and secondary cullet, on the basis of which most of the methods of obtaining this material have been developed. Practically all of the so-called primary or process cullet formed in glass plants is returned into production, conserving raw materials and energy. For this reason, developers usually stop their search at secondary cullet — household wastes of sheet, container and other forms of glass [3].

In the countries of the Commonwealth of Independent States, including in Russia and Kazakhstan, the problem of using secondary cullet is associated not only with its collection by the public, which process is not organized properly, but also the presence of various impurities in it, which greatly impedes the development of an unified technology for processing cullet into foam glass. All this makes it necessary to improve the technological approaches to obtaining foam glass directed toward using a raw material which is an alternative to cullet. Possible alternatives are widely available natural and technogenic materials, which prior to foaming can be converted into a glassy state — a necessary condition for obtaining foam glass. However, melting glass, irrespective of composition, is an expensive energy consuming operation, even without the fining stage. Since silicate and glass formation can proceed at temperatures close to the foaming region [4], the use of widely available forms of natural and technogenic silicate raw material as raw materials is a promising trend in the development of foam glass technology.

Opokas, which are high-silica rocks of sedimentary and chemical origin, could become promising raw material for the production of heat-insulating foam glass. The opoka reserves exceed 1×10^6 tons [5 – 8].

The aim of the present investigation is to determine the possibility of obtaining foam glass by low-temperature processing of opoka at temperatures below 900°C directly from a mixture of raw materials based on silica rock, bypassing the vitrification process, as well as to study the properties of the material obtained. The experimental work was performed on the basis of opoka from the Kyngrakskoe deposit, whose reserves exceed 0.5×10^6 tons. Tests of quartz sand were performed in parallel.

It is well known that opokas consist of an amorphous mass of opal and finely dispersed clayey substances (hydromica and a very small amount of montmorillonite) with impurities comprised of grains of quartz, glauconite, limonite, feldspars and muscovite flakes (to 10%). Opal is colloform in the bulk. Relict residues of radiolarian, likewise folded with opal, are rarely encountered [5 – 8].

Data obtained from analyses, petrographic, optical and scanning electron microscopy and chemical, x-ray phase and x-ray fluorescence microanalysis show the following to be present in the opoka studied (%[4]): clayey-opaline material — 78, secondary quartz — 10, iron aluminosilicate in the form of glauconite — 5, iron hydroxide — 2 – 3, mica — 2 and feldspar, zircon — 1. Examples of the images of diffe-

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[4] Here and below, content by weight, %.

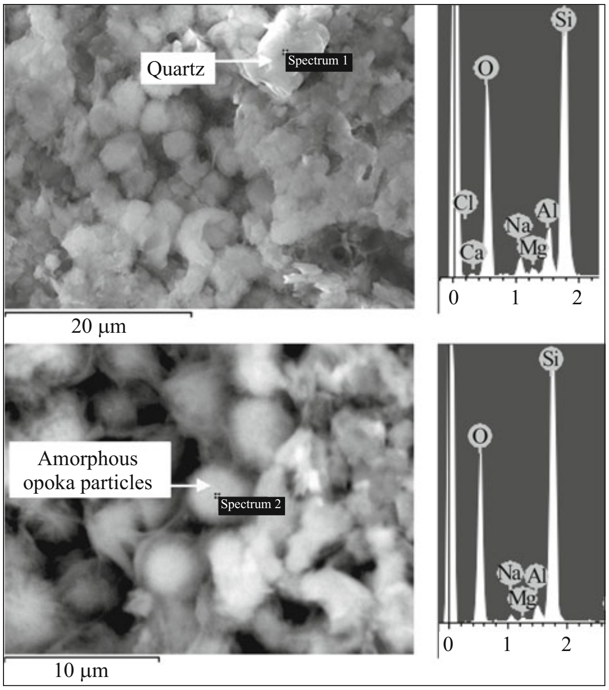

Fig. 1. SEM images of different fragments of opoka and data from x-ray fluorescence microanalysis.

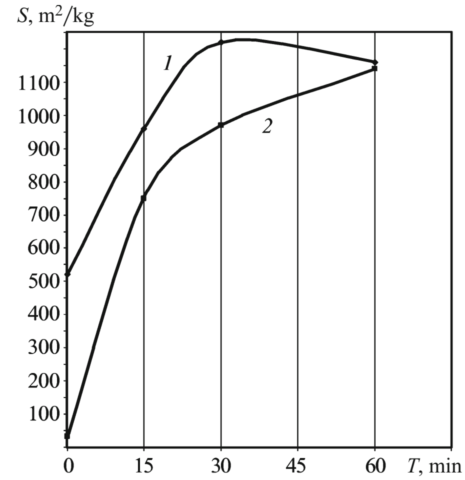

Fig. 2. Specific surface area of opoka and quartz sand versus the milling time in a planetary mill.

rent fragments of the material studied and identification of the composition of individual particles are presented in Fig. 1.

Chemical analysis shows that the opoka studied is characterized by a high content of silicon, aluminum and iron oxides. The average chemical composition of the opoka from the Kyngrakskoe deposit is as follows (wt.%): 78.3 SiO_2, 8.2 Al_2O_3, 2.9 Fe_2O_3, 0.3 TiO_2, 1.9 CaO, 1.4 MgO and 7.0 other.

It is well known that the sintering intensity and the parameters of the porous structure of the material depend on many factors (mixture composition, sintering temperature and milling conditions, reaction rates and so forth). In the present work we studied the effect of the milling time, NaOH content and sintering temperature on pore formation in Kyngrakskoe opoka.

A planetary mill was used for dry fine comminution of opoka powder. The effect of the comminution time on the dispersity of the powder was determined, using a PSKh-11 (SP) apparatus, from the change in the specific surface area. The data obtained are presented in Fig. 2.

It is evident from Fig. 2 that the optimal milling time is 30 min. The long duration of the process did not give comminution of the opoka particles, which were even observed to increase in size, possibly because of aggregation of small individual particles into larger formations.

Pre-weighed opoka powders and quartz sand with different specific surface area were carefully mixed with an alkaline solution of 10, 13, 15, 17 and 20% NaOH concentration to a paste-like state. The mixtures obtained were heat-treated in a furnace at temperatures from 800 to 900°C and the soaking time was 30 min.

The prospects for opoka as a foaming base is clearly seen from its comparison with quartz sand in the foaming process: mixtures based on opoka make it possible to obtain blocks of foamed material, while mixtures in which quartz sand served as the raw material showed only a capability to form loose sinters with no visible pores characteristic of foam materials for all experimental concentrations of sodium hydroxide and sintering temperatures. There is not enough time for quartz grains to dissolve in sodium hydroxide, while gases released from the mixture through leaky sinter escape into the atmosphere and do not form bubbles and cavities in the material. The sintering temperature interval where intense pore formation is observed in opoka lies between 800 and 900°C. At 800°C no pores are formed yet. Even at 900°C a glassy film forms on the surface of the block. For this reason the temperature interval near 850°C must be regarded as optimal for pore formation in these opokas.

The concentration of sodium hydroxide in the water, the optimal value being 13%, added to the mixture has a strong effect on the structure of opoka and its properties. For alkali content 10% or less the structure of the samples differed by inadequate porosity, to which the high values of the porosity (> 500 kg/m^3) attest. Higher NaOH content (15, 17 and 20%) resulted in the formation of an open structure with large pores and caverns up to 10 mm in size, interconnected by labyrinthine channels, which promotes growth of the water absorption by the samples. At the same time the optimal structure for foam glass is considered to be characterized by a large number of fine pores up to 5 mm in size, isolated from one another by very thin walls. Typical samples of the foamed material obtained are presented in Fig. 3.

It is evident from Fig. 4 that for the chosen sintering regime at 850°C, owing to the change in the milling time and NaOH content, the porosity of the foamed opoka materials

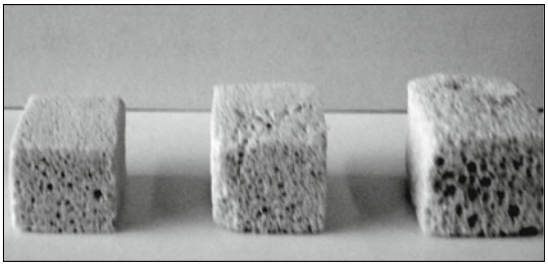

Fig. 3. Foam glass samples obtained with density (left to right) 400, 370 and 340 kg/m^3.

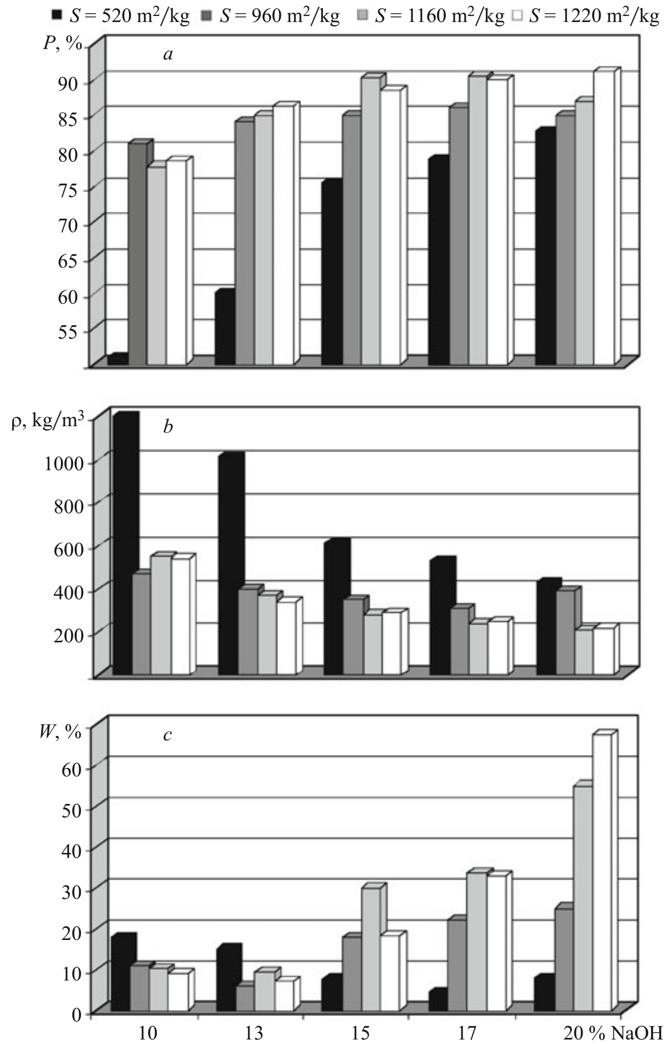

Fig. 4. Porosity P (a), density ρ (b) and water absorption W (c) of foam glass versus the specific surface area S of the powder of the opoka used and NaOH mass fraction in the solution mix in.

can change over a wide range from 50 to 95%. The value of this parameter as well as the character of the porous structure determine the properties of the material obtained, such as, the density, which shows that ratio of the solid and gaseous phases in the material, and water absorption, attesting to the fraction of open (communicating) pores out of the total number of pores.

An increase of the pore content in a material results in improved heat-insulation. In this connection materials with high porosity and, correspondingly, low density give the best heat-insulation properties. From this standpoint the best indicators for foam glass are obtained using opoka with specific surface area $S = 960$ and 1220 m^2/kg and using a mixing solution with sodium hydroxide content 15 – 20%. At the same time it is known that the fine porous structure with a large number of fine isolated pores is preferable to a coarse-grain structure with high water absorption, when large pores-caverns communicate with one another, even if the total porosity of the latter is several-fold higher.

On the basis of this and the experimental data the opoka powder with specific surface area 950 – 1250 m^2/kg and a solution with sodium hydroxide content about 13% are optimal for obtaining foam glass by the method proposed above.

In summary, it has been established that it is in principle possible to use opoka from the Kyngrakskoe deposit as raw material for obtaining heat-insulating foam glass by means of a technology with no melting process. The optimal sintering temperature, powder dispersity and mass content of sodium hydroxide as an additive, which ensure the formation from opoka of an amorphous foamed material, were determined.

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